NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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INFLUENCE OF TAIL LENGTH UPON THE SPIN-RECOVERY CHARACTERISTICS OF A TRAINER-TYPE-AIRPLANE MODEL

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Vertical Wind Tunnel

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SUMMARY

An investigation has been conducted to determine the effect of tail length on the spin and recovery characteristics of a model typical of a trainer-type airplane. The model used in the investigation was tested with two tail lengths, and the model having the shorter tail length was tested with several ventral fins installed in order to improve its recovery characteristics.

The investigation showed that the model with the longer tail length had the better recovery characteristics even when the short-tail model had comparable or even higher values of tail-damping power factor.

INTRODUCTION

Reference 1 presents a method for designing an airplane for satisfactory spin recovery based upon an empirical relationship between a tail-damping power factor and relative density and mass distribution. Results of recent investigations in the Langley 20-foot free-spinning tunnel have indicated that tail length may have a greater influence on the spin-recovery characteristics of airplanes than is usually indicated by the tail-damping power factor. The present investigation was undertaken to obtain further information on the effect of tail length. The model used for the investigation was considered representative of a typical single-engine trainer-type airplane with regard to both dimensional and mass characteristics. Two values of tail length and several values of tail-damping power factor were investigated. Erect spins only were tested.

SYMBOLS

b wing span, feet

l tail length, distance from center of gravity to rudder hinge line, feet

S	wing area, square feet
$\bar{c}$	mean aerodynamic chord of wing, feet
$x/\bar{c}$	ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord of wing to mean aerodynamic chord of wing
$z/\bar{c}$	ratio of distance between center of gravity and fuselage reference line to mean aerodynamic chord of wing (positive when center of gravity is below fuselage reference line)
m	mass of airplane, slugs
I_X, I_Y, I_Z	moments of inertia about X, Y, and Z body axes, respectively, slug-feet^2
$\dfrac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter
$\dfrac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter
$\dfrac{I_Z - I_X}{mb^2}$	inertia pitching-moment parameter
ρ	air density, slug per cubic foot
μ	relative density of airplane $\left(\frac{m}{\rho Sb}\right)$
α	angle between fuselage reference line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), degrees
ϕ	angle between span axis and horizontal, degrees
V	full-scale true rate of descent, feet per second
Ω	full-scale angular velocity about spin axis, revolutions per second

TDR	tail-damping ratio (fig. 1 of reference 1)
URVC	unshielded rudder volume coefficient (fig. 1 of reference 1)
TDPF	tail-damping power factor (fig. 1 of reference 1)

APPARATUS AND METHODS

Model

The model used for the investigation was arbitrarily considered to be a $\frac{1}{18}$-scale model of a typical trainer airplane, and the dimensional characteristics of the corresponding full-scale airplane are given in table I. Figure 1 is a three-view drawing of the model with the long tail length. The long and short tail lengths investigated are shown in figure 2. When the tail length was decreased, the horizontal tail was raised and a 0.50-inch ventral fin was added in order to maintain approximately the same values of tail-damping ratio and unshielded rudder volume coefficient (fig. 1 of reference 1) for both the long and short tail lengths. (See table II.) The three ventral fins investigated on the model having the short tail length are shown in figure 3.

The model was ballasted with lead weights to obtain dynamic similarity to the corresponding airplane at an altitude of 10,000 feet (ρ = 0.001756 slug/cu ft). A remote-control mechanism was installed in the model to actuate the rudder and elevator for recovery tests. Sufficient hinge moments were applied to the controls during recovery attempts to reverse them fully and rapidly.

Wind Tunnel and Testing Technique

The tests were performed in the Langley 20-foot free-spinning tunnel, the operation of which is, in general, similar to that described in reference 2 for the 15-foot free-spinning tunnel except that the model-launching technique has been changed. With the controls set in the desired position the model is now launched by hand with rotation into the vertically rising air stream. After a number of turns, the model assumes its spin attitude and is maintained at a specified level in the tunnel by adjusting the airspeed so that the rate of descent of the model corresponds to the velocity of the vertically rising air stream. The model is shown spinning in the Langley 20-foot free-spinning tunnel in figure 4.

After a number of turns in the established spin, a recovery attempt is made by moving one or more controls by means of a remote-control mechanism. After recovery, the model dives or glides into a safety net. The spin data obtained from the tests are then converted to corresponding full-scale values by methods described in reference 2.

In accordance with standard spin-tunnel procedure, tests were performed to determine the spin and recovery characteristics for the normal control configuration for spinning (elevator full up, ailerons neutral, and rudder full with the spin) and for other aileron-elevator combinations including neutral and maximum settings of the control surfaces for various model conditions. Recovery was generally attempted by reversal of the rudder from full with the spin to full against the spin. Tests were also performed to determine the effect of small variations in control deflections on recoveries from the normal spin control configuration. For these tests, the elevator was set at only two-thirds full up and the ailerons were set at one-third of the full deflection in the direction conducive to slower recoveries (ailerons against the spin for this model). Recovery from this spin was attempted by reversing the rudder from full with to two-thirds against the spin either alone or in conjunction with moving the elevator to one-third down. This control configuration and movement of the controls is referred to herein as the "criterion spin". The turns for recovery were measured from the time the controls were moved until the spinning rotation ceased. The criterion for a satisfactory recovery from a spin in the spin tunnel has been adopted as $2\frac{1}{4}$ turns or less based primarily on the loss of altitude of the airplane during the recovery and subsequent dive.

For spins which have a rate of descent in excess of that which can be readily attained in the tunnel, the rate of descent is recorded as greater than the velocity at the time that the model hits the safety net; for example, > 300 feet per second. For these tests, the recovery recorded is somewhat conservative inasmuch as recovery is generally attempted before the model reaches its final steep attitude and while the model is still descending in the tunnel.

PRECISION

The model test results presented are believed to be the true values given by the model within the following limits:

α, degrees	±1
ϕ, degrees	±1
V, percent	±5
Ω, percent	±2

Turns for recovery:

When obtained from film records	±1/4
When obtained visually	±1/2

The preceding limits may have been exceeded for certain spins in which it was difficult to control the model in the tunnel because of the high rate of descent or because of the wandering nature of the spin.

Comparison between model and airplane spin results (references 2 and 3) indicates that spin-tunnel results are not always in complete agreement with airplane spin results. In general, the models spun at a somewhat smaller angle of attack, at a somewhat higher rate of descent, and with 5° to 10° more outward sideslip than did the corresponding airplanes. The comparison made in reference 2 for 21 airplanes showed that approximately 80 percent of the model recovery tests predicted satisfactorily the corresponding airplane recovery characteristics and that approximately 10 percent overestimated and approximately 10 percent underestimated the airplane recovery characteristics.

Because of the impracticability of ballasting the model exactly and because of inadvertent damage to the model during tests, the weight and mass distribution of the model varied within the following limits:

Weight, percent . . . . 0 to 1 high
Center-of-gravity location, percent $\bar{c}$ . . . . 0 to 1 rearward

Moments of inertia:
- I_X, percent . . . . 1 low to 8 high
- I_Y, percent . . . . 0 to 1 high
- I_Z, percent . . . . 0 to 4 high

The measurement of the mass characteristics were made within the following limits of accuracy:

Weight, percent . . . . ±1
Center of gravity, percent $\bar{c}$. ±1
Moments of inertia, percent . . . . ±5

The controls were set with an accuracy of $\pm 1^{\circ}$.

TEST CONDITIONS

Table II lists the various configurations tested on the model. The mass characteristics and inertia parameters for the normal loading condition tested for each model configuration are listed in table III. The inertia parameters are also plotted in figure 5. As discussed in reference 4, plots of these parameters can be used in predicting the relative effectiveness of the controls on the recovery characteristics of the airplane.

The normal maximum control deflections used were:

Rudder, degrees	30 right, 30 left
Elevator, degrees	30 up, 10 down
Ailerons, degrees	19 up, 19 down

RESULTS AND DISCUSSION

The results of the model tests are presented in charts 1 and 2. The results for left and right spins were generally similar and are arbitrarily presented in terms of equivalent right spins. Data are presented in terms of full-scale values at an altitude of 10,000 feet.

The data presented in chart 1 show the effect of varying the tail length of the fuselage. It is apparent from the data presented in the chart that the model with the short tail length $\left(\frac{l}{b} = 0.41\right)$ and the 0.50-inch ventral fin installed had unsatisfactory recovery characteristics based on the "criterion spin", whereas the model with the long tail length $\left(\frac{l}{b} = 0.53\right)$ exhibited excellent recovery characteristics. The tail-damping power factor for these two configurations was approximately the same (table II). Adding larger ventral fins improved the recovery characteristics of the short-tail-length model (chart 2) and when the 1.00-inch ventral fin was installed, the recovery characteristics of the model were considered to be satisfactory. It is of interest to note that the over-all recovery characteristics of the long-tail-length model $\left(\text{TDPF} = 395 \times 10^{-6}\right)$ were better than the recovery characteristics of the short-tail-length model with the 1.00-inch ventral fin installed $\left(\text{TDPF} = 517 \times 10^{-6}\right)$, even though the long-tail-length model had a lower value of tail-damping power factor.

The results of the investigation indicate that the damping in the spin increased as the tail became further removed from the wing. For the short-tail-length model $\left(\frac{l}{b} = 0.41\right)$ the vertical tail and the rearward portion of the fuselage may have been somewhat shielded by the wing during the spin, but when the tail length was increased a greater part of the tail may have become exposed to the air stream and thus have become more effective in damping out the spin rotation. In addition, the extra fuselage side area added when the tail surfaces were moved rearward probably contributed toward improving the spin-recovery characteristics as has been indicated by the work of W. Tye and S. V. Fagg in England.

CONCLUSIONS

Based on the results of the investigation, the following conclusions are made:

1. The recovery characteristics of an airplane may be influenced by the airplane tail length to a greater extent than is indicated by the value of the tail-damping power factor.

2. An increase in tail length offers a more effective means of improving the spin-recovery characteristics than an addition of ventral-fin area.

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2. Zimmerman, C. H.: Preliminary Tests in the N.A.C.A. Free-Spinning Wind Tunnel. NACA Rep. No. 557, 1936.

3. Seidman, Oscar, and Neihouse, A. I.: Comparison of Free-Spinning Wind-Tunnel Results with Corresponding Full-Scale Spin Results. NACA MR, Dec. 7, 1938.

4. Neihouse, A. I.: A Mass-Distribution Criterion for Predicting the Effect of Control Manipulation on the Recovery from a Spin. NACA ARR, Aug. 1942.

TABLE I.-FULL-SCALE DIMENSIONAL CHARACTERISTICS OF THE

AIRPLANE REPRESENTED BY THE $\frac{1}{18}$-SCALE MODEL

Over-all length, ft:	
Long tail length	31.6
Short tail length	26.7
Wing:	
Span, ft	41.6
Area, sq ft	236.0
Aspect ratio	7.4
Chord, in.	
Root	89.9
Mean aerodynamic chord	70.7
Tip (design)	47.0
Taper ratio (design tip chord, root chord)	0.52
Location of mean aerodynamic chord, in.	
Leading edge of $\bar{c}$ rearward of leading edge of root chord	4.8
Leading edge of $\bar{c}$ below center line of fuselage	10.9
Angle of incidence, deg	
Root	3.00
Mean aerodynamic chord	1.21
Tip	-1.00
Angle of geometric dihedral (in wing reference plane), deg	5.00
Angle of sweepback (at leading edge of wing), deg	2.50
Airfoil section	
Root	NACA 2416
Tip	NACA 4409
Ailerons:	
Area (both ailerons), sq ft	
Total	20.9
Rearward of hinge line	15.9
Span, in.	108.0
Horizontal tail surfaces:	
Area, sq ft	
Total	47.38
Elevator	
Total	20.08
Rearward of hinge line	17.02
Span, ft	13.17
Distance from center of gravity to elevator hinge line, in.	
Long tail length	252.7
Short tail length	194.2
Vertical tail surfaces:	
Total area, sq ft	20.97
Rudder	
Total	12.50
Rearward of hinge line	10.57
Span, ft	6.06
Distance from center of gravity to rudder hinge line, in.	
Long tail length	266.4
Short tail length	207.9

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TABLE II.- CONFIGURATIONS TESTED ON THE MODEL

Tail length	$\frac{l}{b}$	Depth of ventral fin (fig. 4) (in.)	Data presented on	Tail damping ratio (reference 1)	Unshielded rudder volume coefficient (fig. 1 of reference 1)	Tail-damping power factor (reference 1)
Long	0.53	None	Chart 1	0.0263	0.0150	395×10^{-6}
Short	.41	0.50	Chart 1	.0261	.0160	418
Short	.41	0.75	Chart 2	.0293	.0160	469
Short	.41	1.00	Chart 2	.0323	.0160	517

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TABLE III.- MASS CHARACTERISTICS AND INERTIA PARAMETERS TESTED ON MODEL

[Model values are presented in terms of full-scale values.]

Configuration	Tail length	Depth of ventral fin (in.)	Weight (lb)	Airplane relative density, μ		Center-of-gravity location		Moments of inertia (slug-feet^2)			Inertia parameters		
				Sea level	10,000 feet	$x/\bar{c}$	$z/\bar{c}$	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
1	Long	None	8436	11.2	15.1	0.275	0.021	4193	9397	12,979	-115×10^{-4}	-79×10^{-4}	194×10^{-4}
2	Short	$\left\{\begin{matrix} 0.50 \\ .75 \\ 1.00 \end{matrix}\right\}$	8441	11.2	15.2	.272	.016	4095	9303	12,870	-115	-79	194

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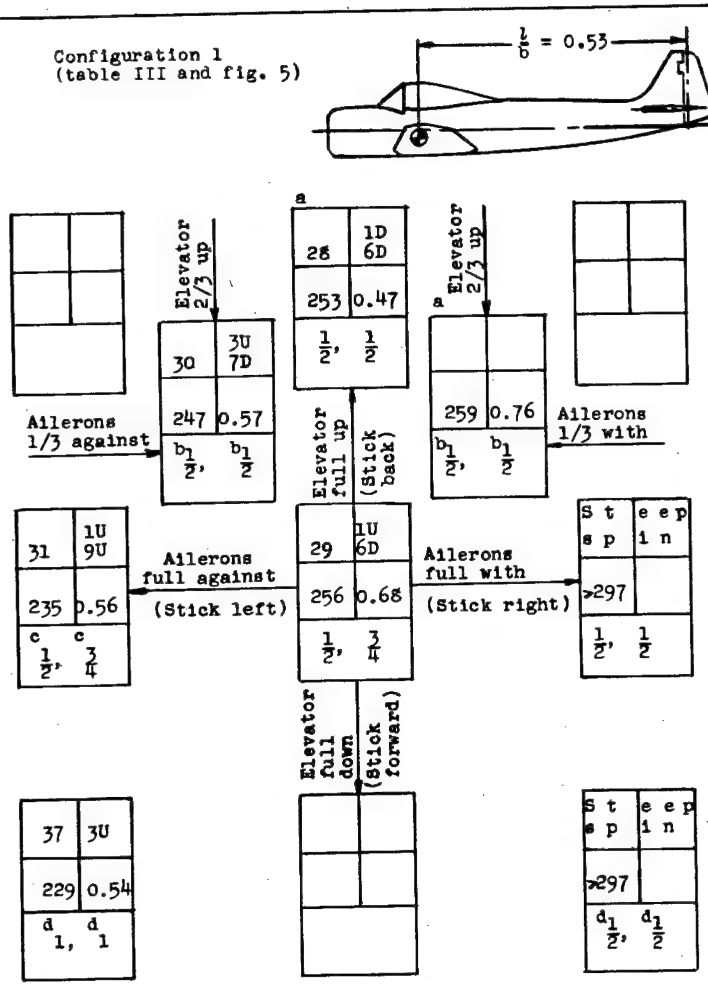
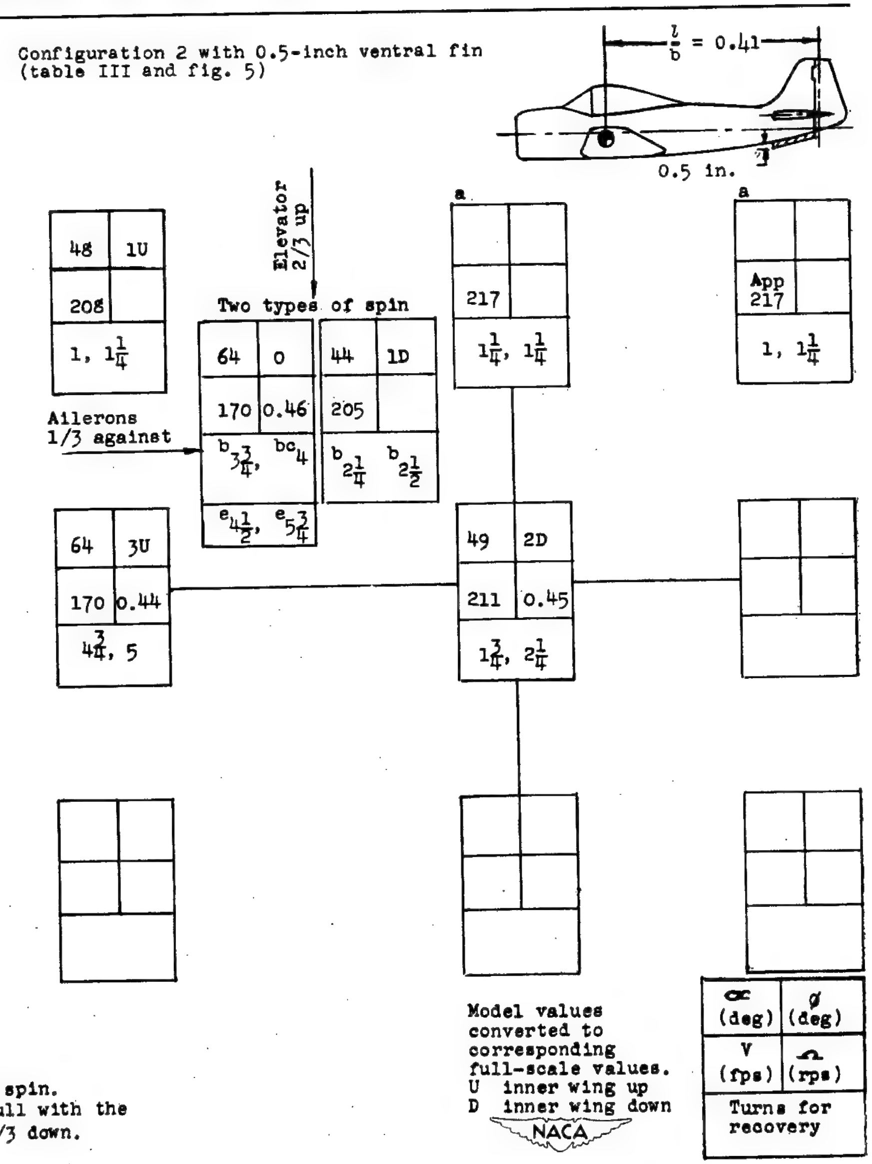
CHART 1.- EFFECT OF TAIL LENGTH ON THE SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted from and steady-spin data presented for rudder-full-with spins; recovery attempted by full rudder reversal unless otherwise indicated; right erect spins]





[a]Model wanders.
[b]Recovery attempted by moving the rudder from full with the spin to 2/3 against the spin.
[c]Visual estimate.
[d]After recovery from the erect spin, the model enters an inverted spin.
[e]Recovery attempted by simultaneously reversing the rudder from full with the spin to 2/3 against the spin and the elevator from 2/3 up to 1/3 down.

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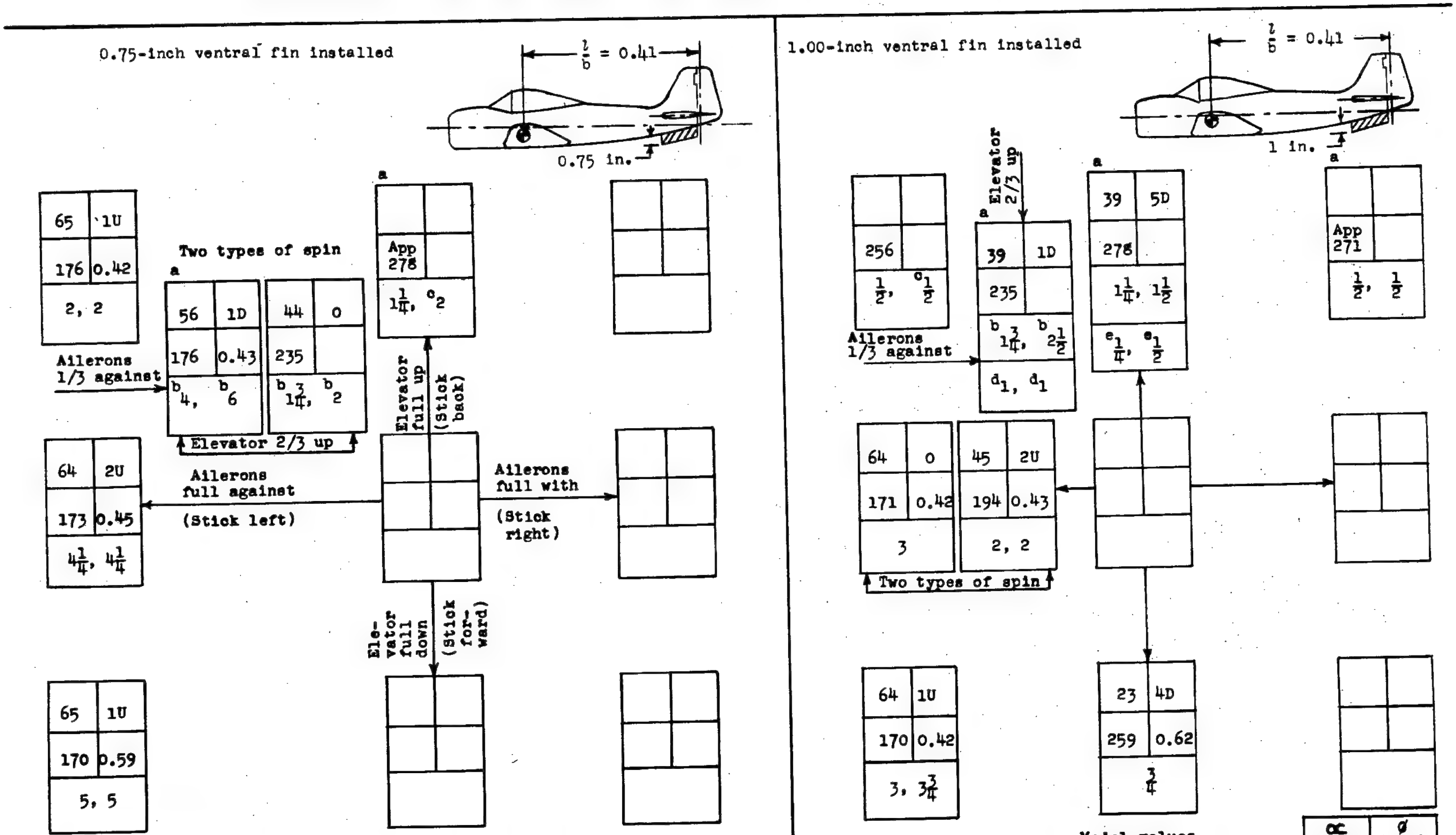
CHART 2.- EFFECT OF VENTRAL FINS ON THE SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Configuration 2 (table III and fig. 5). Recovery attempted from and steady-spin data presented for rudder-full-with spins; recovery attempted by full rudder reversal unless otherwise indicated; right erect spins]



[a]Model wanders.
[b]Recovery attempted by moving the rudder from full with the spin to 2/3 against the spin.
[c]Visual estimate.
[d]Recovery attempted by simultaneously reversing the rudder from full with the spin to 2/3 against the spin and the elevator from 2/3 up to 1/3 down.
[e]Recovery attempted by simultaneously reversing the rudder from full with the spin to 2/3 against the spin and the elevator from full up to 1/3 down.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

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α (deg)	ϕ (deg)
V (fps)	Ω (rps)
Turns for recovery	

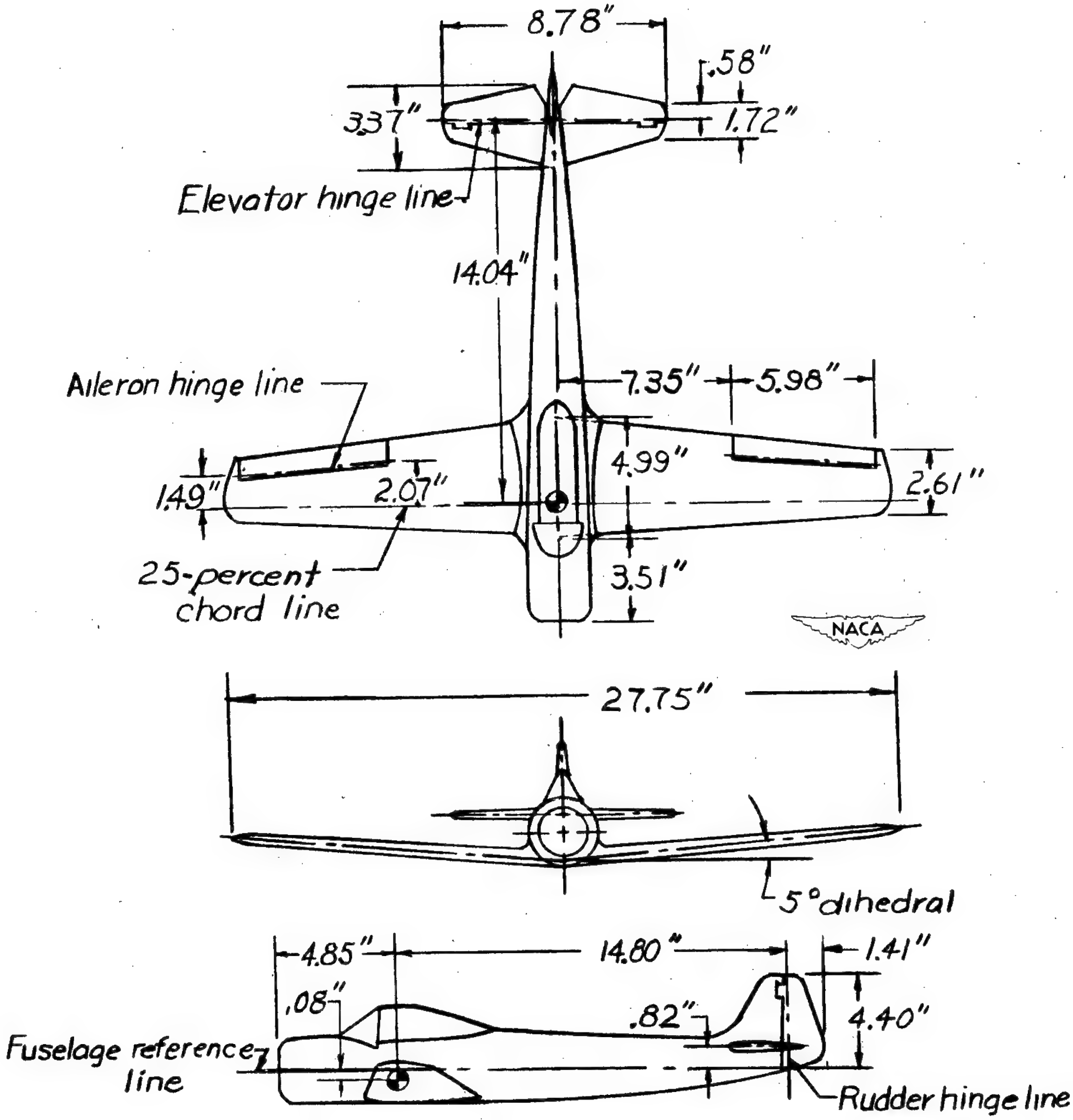

Figure 1.- Three-view drawing of model with long tail length as tested in the Langley 20-foot free-spinning tunnel. Center of gravity at 27.5 percent mean aerodynamic chord.

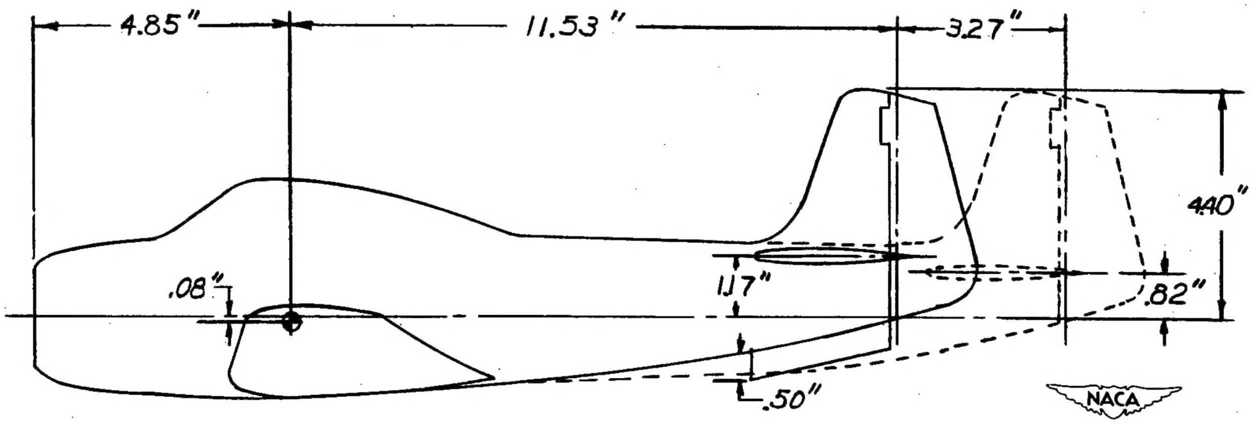

Figure 2.- Comparison of the long and short tail lengths tested on the model. Center of gravity at 27.5 percent mean aerodynamic chord.

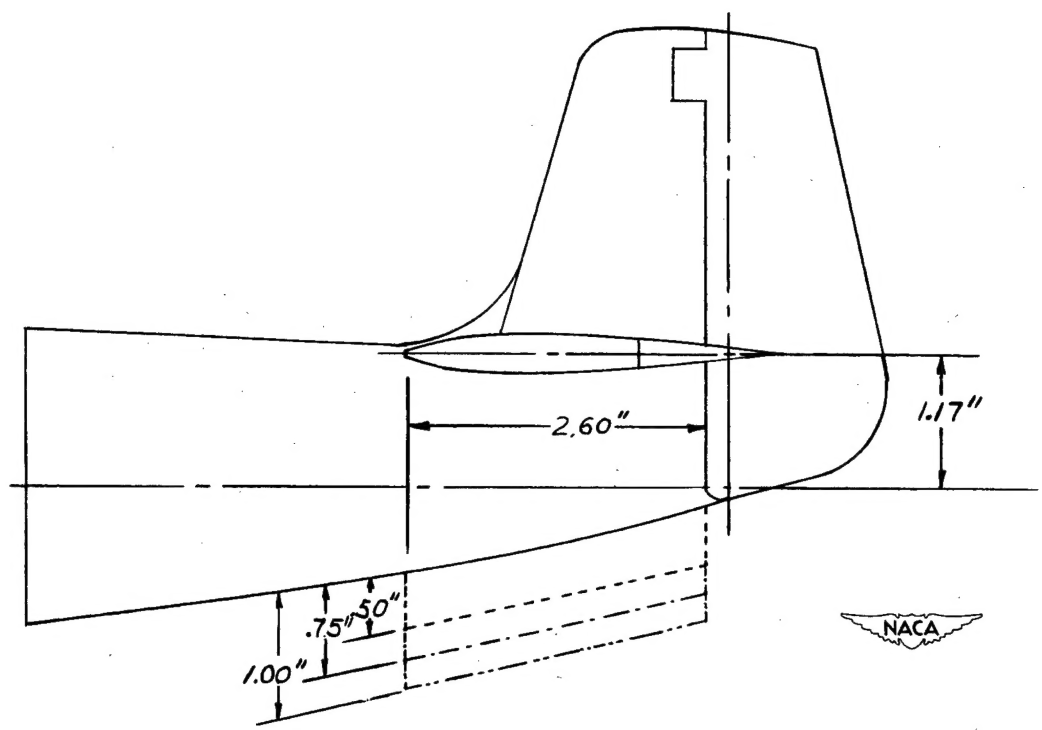

Figure 3.- Size and location of ventral fins tested on model with short tail length installed.

Figure 4.- Photograph of the model spinning in the Langley 20-foot free-spinning tunnel.

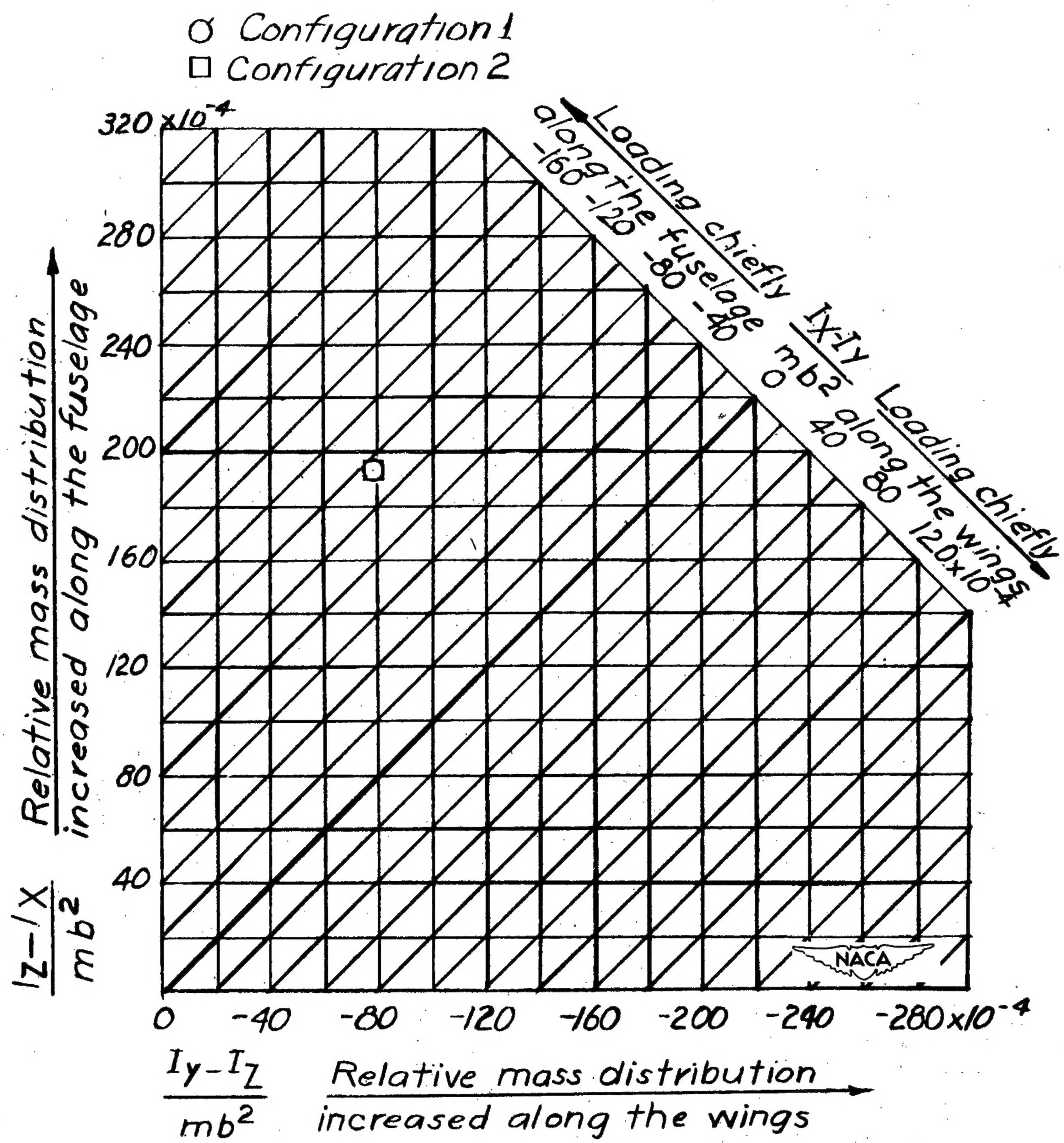

Figure 5.- Inertia mass parameters for various model configurations tested. (Loadings listed in table III.)

INFLUENCE OF TAIL LENGTH UPON THE SPIN-RECOVERY

CHARACTERISTICS OF A TRAINER-TYPE-AIRPLANE MODEL

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ABSTRACT

An investigation has been conducted in the Langley 20-foot free-spinning tunnel to determine the effect of tail length on the spin-recovery characteristics of a model of a typical trainer-type airplane. The model was tested with two tail lengths. Both tail lengths were tested at essentially the same loading condition.

The results of the investigation indicated that the recovery characteristics of an airplane may be influenced by the airplane tail length to a greater extent than is indicated by the value of the tail-damping power factor.